METHODS AND COSTS OF PRODUCING BROWN IRON ORE AT TWO SMALL SOUTHERN MISSOURI MINES

By H. D. Kline

* * * * * * * * * * * * information circular 7983

UNITED STATES DEPARTMENT OF THE INTERIOR
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METHODS AND COSTS OF PRODUCING BROWN IRON ORE AT TWO SMALL SOUTHERN MISSOURI MINES[1/]

by

H. D. Kline[2/]

INTRODUCTION

This paper describes the methods of mining and washing brown iron ore in 1957 at the Sawyer mine, leased by Wayne County Mining Co., and the Fore mine, leased by Four Mining Co., both in southern Missouri; it is one of a series prepared by the Federal Bureau of Mines on mining and milling methods and costs in various districts of the United States.

The Sawyer mine is in Wayne County, about 10 miles north-northeast of Williamsville (fig. 1); the Fore mine is in Howell County, about 20 miles southwest of West Plains (fig. 2). Both are open-pit mines from which the crude ore was upgraded by washing and hand-sorting to produce ore of grade and quality suitable for sale to operators of iron and steel furnaces.

The operations described are typical of many others that produce or have produced marketable brown iron ore from small sedimentary deposits, several hundred of which outcrop on the crests or hill sides of southern Missouri (fig. 3). The 1957 production of marketable brown iron ore by 40 separate operations in the southern part of the State was 281,427 wet long tons, valued at $1,637,243. Production from the Sawyer mine that year was 17,000 dry long tons of washed ore, and from the Fore mine, 20,816 dry long tons.

Ore, unless other wise defined, means material acceptable for blast-furnace feed. Tonnage is given in terms of dry long tons (DLT), or wet long tons (WLT).

ACKNOWLEDGMENTS

Acknowledgment is made to Rufus D. Bratton, co-owner and manager of Wayne County Mining Co., and to Mearl D. Frazier, co-owner and manager of Four Mining Co., for their cooperation in furnishing pertinent information and their permission to publish the operational and cost data presented in this paper.

1/ Work on manuscript completed September 1959.
2/ Mining engineer, Bureau of Mines, Bartlesville, Okla.

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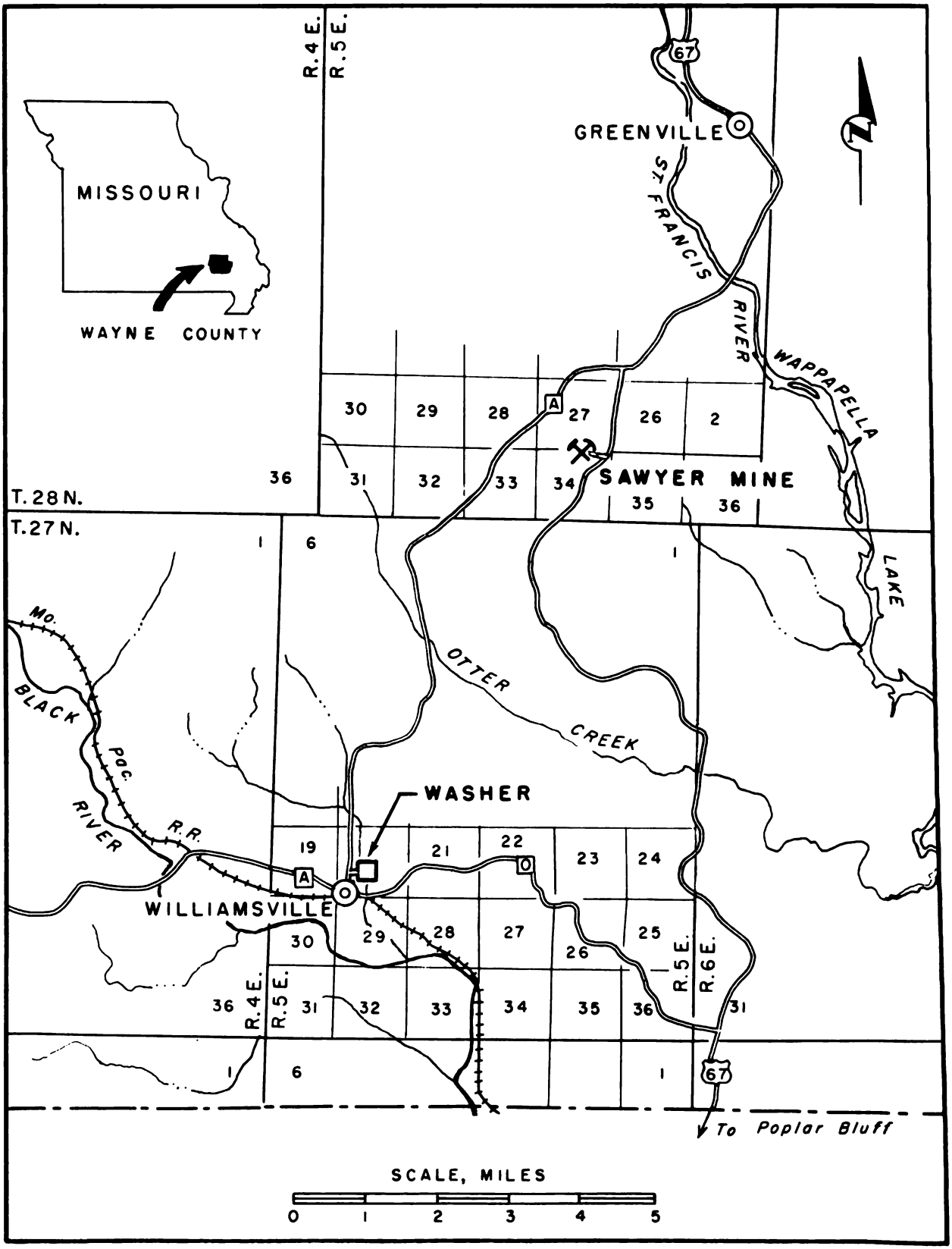

FIGURE 1. - Location Map, Sawyer Mine, Wayne County, Mo.

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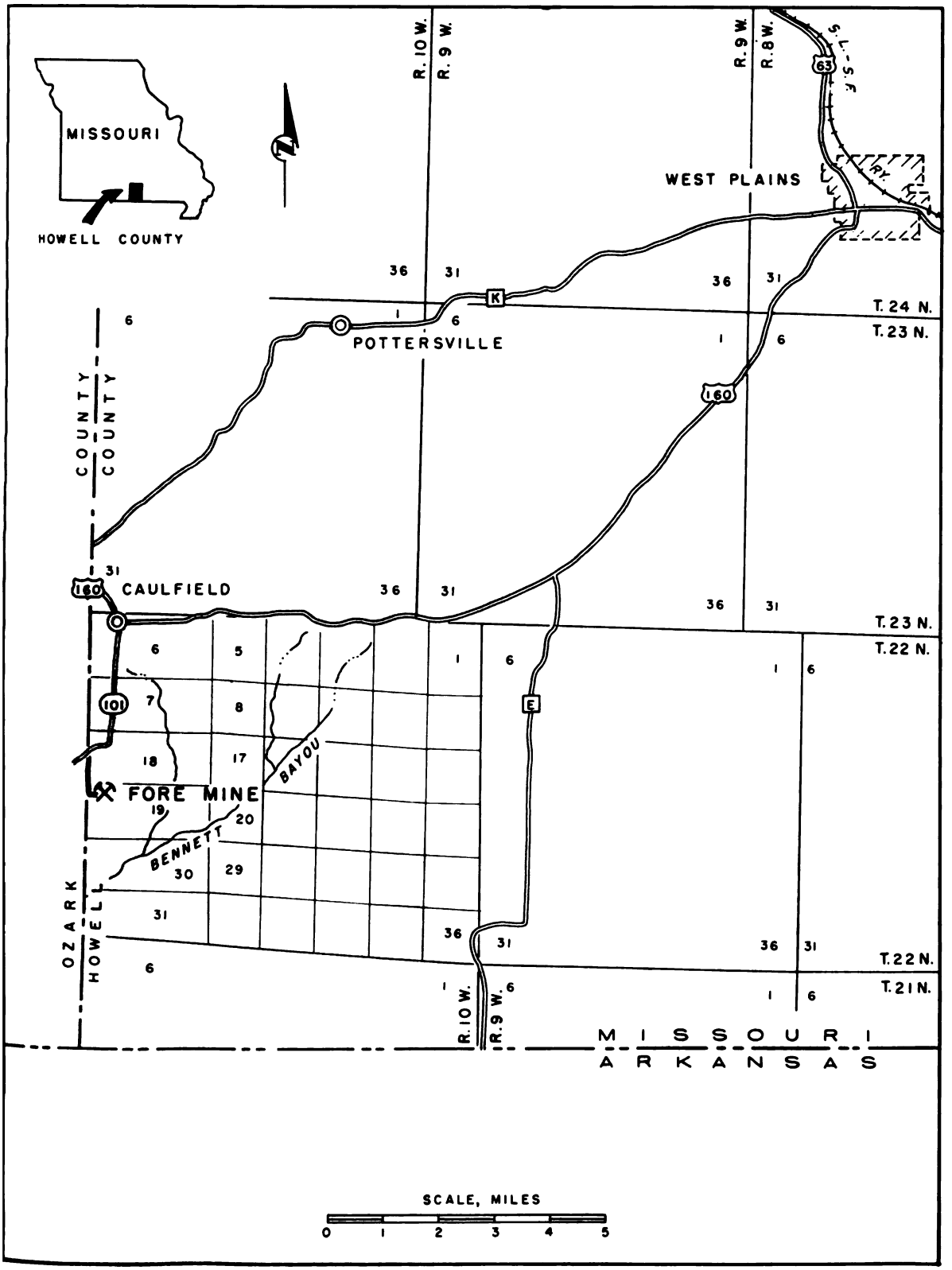

FIGURE 2. - Location Map, Fore Mine, Howell County, Mo.

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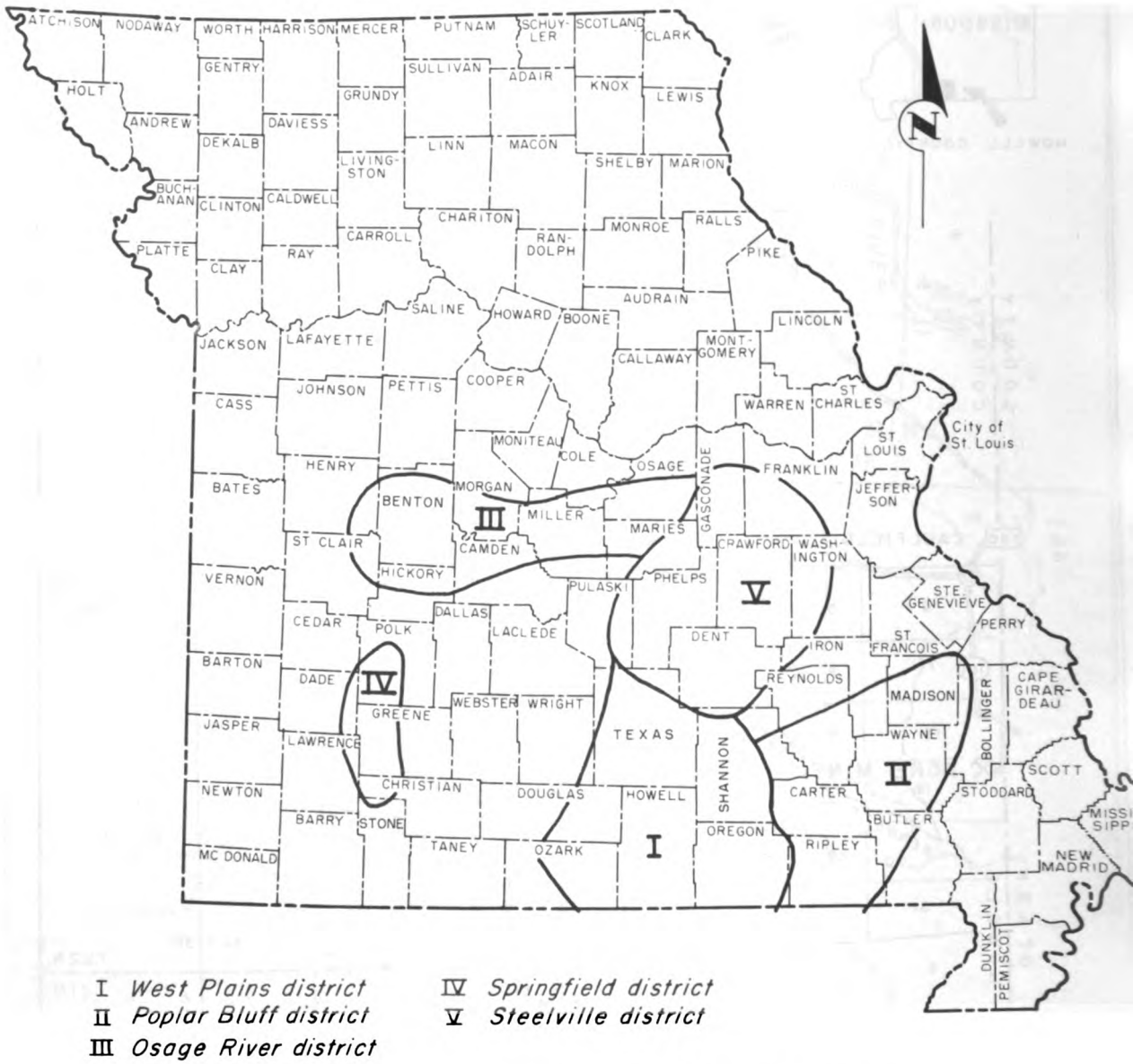

I *West Plains district*
II *Poplar Bluff district*
III *Osage River district*
IV *Springfield district*
V *Steelville district*

FIGURE 3. - Sedimentary Iron Ore Districts of Missouri.

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HISTORY

The occurrence of brown iron ores in southern Missouri was first recorded in 1673, but mining did not begin until about 1870 (2)[3/]. Production from the area through 1958 totaled approximately 1,330,000 dry long tons of shipping-grade ore and concentrates (4, 5, 6). Production in 1957 was 281,427 wet long tons.

The first mining on the Sawyer deposit was in 1905 (2), and the mine has been worked intermittently and by various lessees to the present time. The property is owned or controlled by Mrs. Ethel Styres, St. Petersburg, Fla. Production from the deposit to January 1, 1959, is estimated at 50,000 dry long tons, of which 37,500 was produced by Wayne County Mining Co. while it leased the property from December 1956 to March 1959. Crude ore mined from the deposit by Wayne County Mining Co. was treated in a washer plant built by the company at Williamsville in 1956.

Taskee Mining Co., which succeeded Wayne County Mining Co. as lessee of the Sawyer mine, did considerable drilling on the property, built a washer-jigging plant adjacent to the north end of the deposit, sank a 700-ft. water well near the plant, and in July 1959 began producing ore.

The Fore property was prospected before 1910 (2) but produced only about 500 tons of ore from 1910 through 1955. Early in 1956, Four Mining Co., tenant under a lease from W. P. Fore, of Caulfield, Mo., owner of the property, built a washer near the deposit, opened a pit mine, and produced ore until December 31, 1958, when lack of a market for concentrates forced closing the mine. Total ore output from the deposit was about 40,500 dry long tons, of which 20,816 was produced in 1957.

LOCATION AND PHYSICAL FEATURES

The Sawyer mine is in the NW1/4NE1/4 sec. 34 and the SW1/4SE1/4 sec. 27, T. 28 N., R. 5 E., Wayne County, Mo. (fig. 1). It is one-quarter mile west of U.S. Highway No. 67 and 10 miles northeast of Williamsville (population, 500), through which the main line of the Missouri Pacific Railroad passes. The washer, placed to serve several deposits and used to upgrade the ore from the mine, is at Williamsville.

The Fore mine is in the N1/4 lot 7, sec. 19, T. 22 N., R. 10 W., Howell County, Mo. (fig. 2). The mine is one-half mile south of State Highway No. 101 and 3-1/2 miles south of the junction of U.S. Highway No. 160 and State Highway No. 101 at Caulfield (population, 50). By highway, it is 22 miles from West Plains (population, 5,000), through which the St. Louis-San Francisco Railway passes.

3/ Underlined numbers in parentheses refer to items in the bibliography at the end of this report.

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Both mines are in wooded, rolling-hill country having a maximum topographic relief of about 300 ft. Altitudes near the Fore mine range from 750 to 1,080 ft.; at the Sawyer mine, the altitude is from 450 to 725 ft.

The climate is mild. Average mean annual temperature is 60° F.; normal annual precipitation is about 45 in.

Drainage from the area surrounding the Sawyer mine is eastward into the St. Francis River; from the vicinity of the Fore mine it is westward into North Fork of White River. There is enough water available for mining and washing operations.

GEOLOGY AND ORE DEPOSITS (2)

Most brown-iron deposits of southern Missouri occur in residual materials resting on Jefferson City dolomite, Roubidoux sandstone, or Gasconade dolomite, all of the Ordovician system (see table 1). The residual materials, which consist mainly of clay, chert, and iron oxides, are products of weathering of sedimentary rocks younger than the Jefferson City dolomite.

Deposits of brown iron are widely distributed over the extreme southern part of the State. According to Crane, they are of two types: Primary deposits, formed by direct precipitation of iron oxide; and secondary deposits in which the iron oxides are products of oxidation of marcasite and pyrite. Secondary deposits occur more commonly and have been mined more extensively than primary deposits.

As disclosed by mining, the contents of individual deposits range from a few tons to rarely more than 175,000 tons. Thicknesses range from a few to more than 100 ft., depending on the depth of the host residuum. Outcrops vary in area and shape and are not reliable criteria for judging size or characteristics of ore bodies. The overburden of cherty clay on the deposits ranges from a few inches to about 25 ft. in thickness.

Common ore minerals are the iron oxides, goethite, and/or limonite (4). Gangue materials and impurities in the ore include pyrite, marcasite, quartz and chert (reported as silica in ore analyses), calcite, dolomite, and minor amounts of manganese, copper, and zinc minerals. The phosphorus content of ore shipments seldom exceeds 0.08 pct. but may exceed 0.20 pct. in ores of th Springfield district. The iron oxide minerals occur as hard boulders, tabula ore, pipe ore, and ocher.

The brown-iron deposits at the Sawyer and Fore mines are of secondary type. Both are on or near the tops of broad ridges.

The deposits at the Sawyer mine are in two parallel, north-south trendir troughs in residual material resting on the Roubidoux formation (fig. 4). Within the mined area the troughs are about 200 ft. apart, but exploratory drilling in 1959 indicates that they unite north of the pits. The deposits are more than 1,400 ft. long, from 50 to 100 ft. wide, and averaged 32 ft. ir thickness at the center. The iron occurs as goethite and limonite, ranging i

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particle size from fine claylike ochre to boulders weighing a ton or more. Residual chert and clay are the common gange materials. Overburden reportedly averaged about 8 ft. in thickness.

TABLE 1. - Geologic column, lower Ordovician series, southern Missouri brown-iron-ore district[1/]

Formation	Character of rocks	Thickness, ft.
Jefferson City.....	Dolomite, light gray to buff, very fine crystalline, argillaceous in upper part. Dolomite, light brown to brown, medium crystalline, with smooth oolitic chert in lower part.	190-250
Roubidoux.....	Dolomite, buff to brown, medium crystalline, with much smooth oolitic and sandy chert. Sandstone, rounded and frosted to angular, cross-bedded, with ripple marks; usually weathers to red-brown.	160-270
Gasconade.....	Dolomite, gray, slightly sandy, with very little chert. Cryptozoon reef horizon 80 to 120 ft. below base of Roubidoux. Dolomite, light gray to gray-brown, fine to coarse crystalline, thin to thick bedded, with much white to gray smooth oolitic and white mealy, soft chert. Drusy in the lower 30 ft.	345-530

1/ Prepared by J. S. Wells, Missouri Geol. Survey and Water Res., May 1959.

The Fore deposit is in residual material resting on the Jefferson City formation. The 90-ft. deep pit resulting from mining operations is circular and approximately 250 ft. in diameter at the surface. It tapers in depth to an oval with an east-west length of approximately 120-ft. and an average width of 50 ft. (fig. 5). The ore was similar to that at the Sawyer mine, except that it contained some unaltered iron sulfides. There was no overburden on the deposit.

PROSPECTING AND EXPLORATION

Exploration by Wayne County Mining Co. was done with a Hossfeld prospecting drill with churn-type action. The mobile outfit, including a

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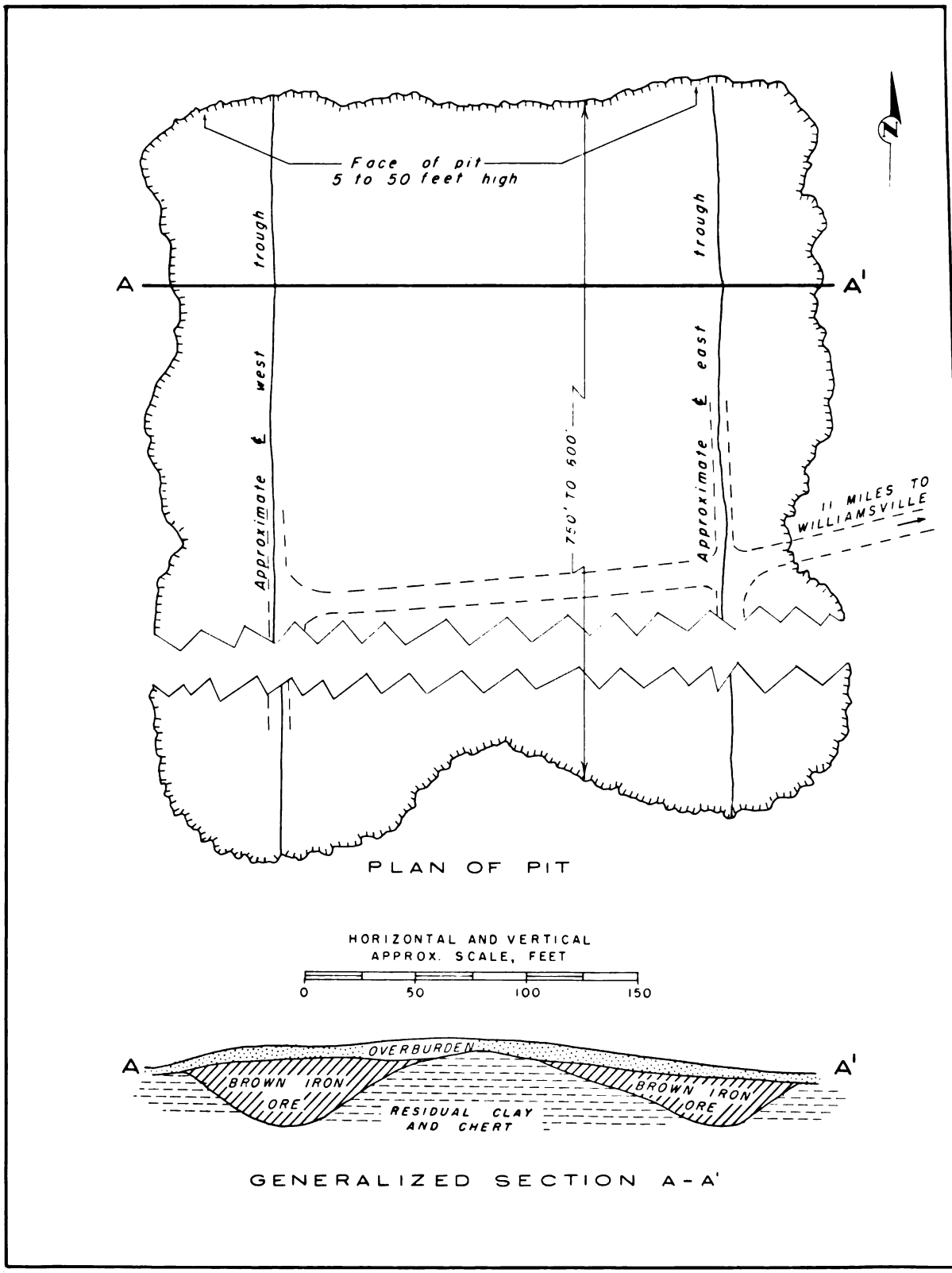

FIGURE 4. - Plan and Section, Sawyer Mine.

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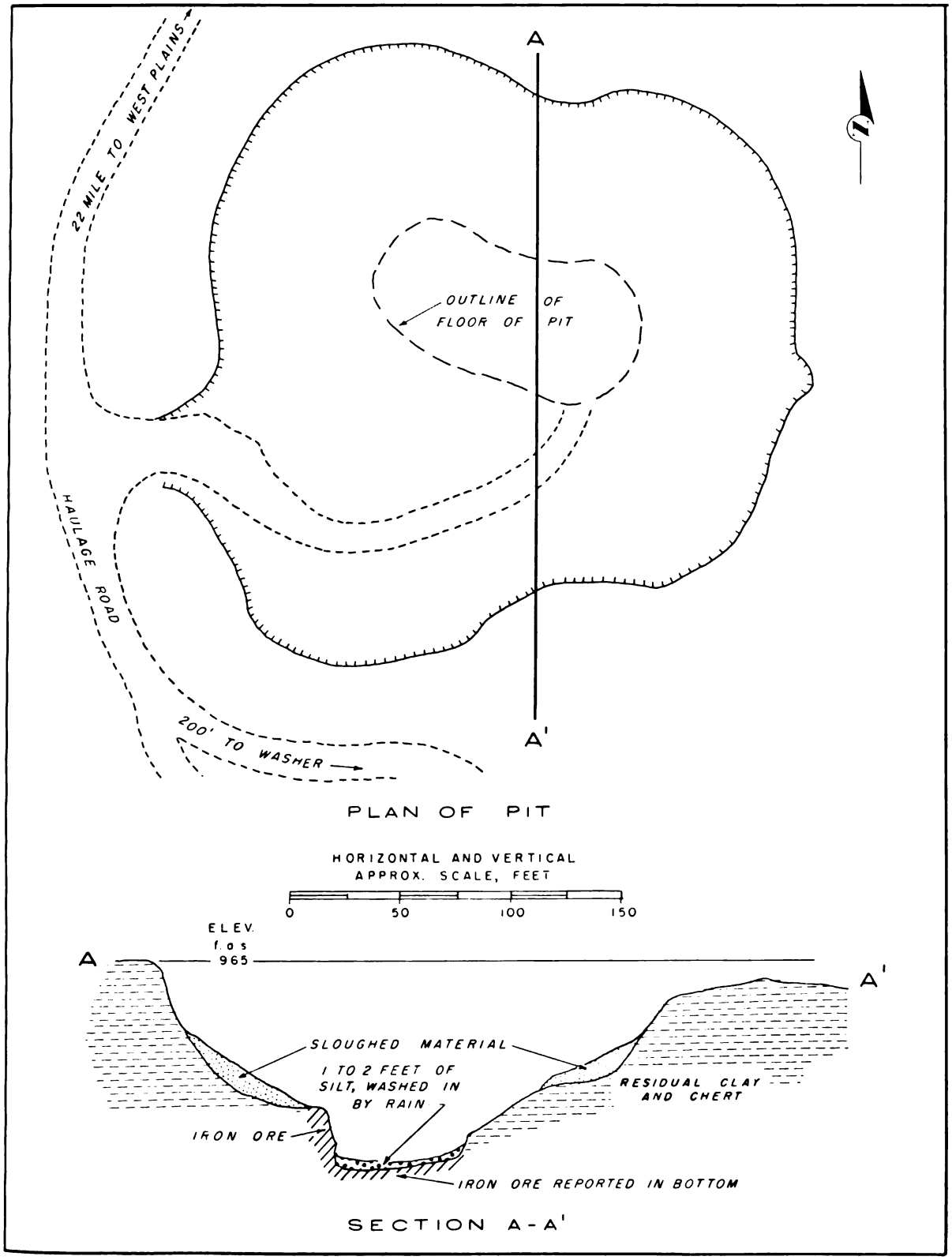

FIGURE 5. - Plan and Section, Fore Mine.

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gasoline-power unit, weighs about 1,300 lb. and is reportedly capable of drilling to depths of 100 ft. Water is hand- or hose-fed into the drill hole; the cuttings are returned to the surface through hollow drill rods. Detachable 2-in.-diameter tungsten-carbide-tipped bits were used on 1-1/2-in.-diameter rods. The drill was normally operated by one man. Ore bodies at the Sawyer mine were partly outlined during 1956 with the Hossfeld unit by drilling thirty-six 2-in.-diameter holes averaging 28 feet in depth.

Prospecting and development work at the Fore mine was done before the Four Mining Co. began operating the property. Two shafts reportedly were sunk into the deposit, one about 50 ft. and the other about 30 ft. In addition, several pits from 3 to 10 ft. deep were dug to outline the deposit at the surface.

The iron content of samples taken from the drill holes on the Sawyer and from the pits and shafts on the Fore was estimated visually.

The reserve of crude, unmined ore in the Sawyer deposit is estimated to be 80,000 long tons averaging 38 pct. iron. Lack of reliable data precluded estimating reserves of unmined ore in the Fore deposit.

MINING AND BENEFICIATION

The open-pit method of mining was used at both mines. Drilling and blast blasting was unnecessary, as power loaders were able to dig the ore without its being otherwise loosened.

The ease of mining and the efficient use of a small labor force, plus mechanization of all phases of the operations, caused labor costs to be low as compared to the total cost of production.

Overburden at the Sawyer mine was removed with a bulldozer; the ore at the Fore mine outcropped at the surface. Most truck loading at the Sawyer mine was done with a crawler-mounted front-end loader equipped with a 2-1/2-cu.-yd.-capacity skip; a front-end loader with a 1-1/2-yd.-skip was used part of the time and for standby purposes.

At the Fore mine, a power shovel with a 1-cu.-yd. dipper was used 40 pct. of the time, and a crawler-mounted front-end loader with a 1-1/2 cu.-yd. skip the remainder of the time (fig. 6). Front-end loaders normally operated on top of the deposits, working toward a bench of ore or country rock to facilitate filling the skip. Teeth on the lips of the skips, or rippers attached to the rear ends of the crawlers, loosened the ore for loading. Loading a 5-cu.-yd.-capacity dump truct required 3 to 5 min.

At both washing plants crude ore was upgraded by similar washing processe using log washers and picking belts (figs. 7 and 8). The crude ore was dumped from trucks into a hopper, from which it passed through a grizzly to the log washer. The feed from the hopper through the grizzly was controlled by being raked by hand or washed down with water under pressure from a nozzle. The grizzlies were constructed of T-rails set parallel with the flanges up and

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FIGURE 6. - Crawler-Mounted Front-End Loader With Ripper and 5-Cubic-Yard Truck, Four Mining Co., Howell County, Mo.

spaced to pass 4-in. material. Boulders that did not pass were broken with a sledge hammer. The washed ore was dropped from the upper end of the washer onto a conveyor belt, on which it was elevated to the ore bin or stockpile. One or two men handpicked waste material from the ore as it was carried toward the discharge end of the belt.

Water for the washers was obtained from ponds formed by damming small nearby streams; the required 450 to 500 g.p.m. was pumped through 4-1/2-in.-diameter pipe for distances up to 500 ft. Tailings were collected in separate ponds to prevent steam pollution.

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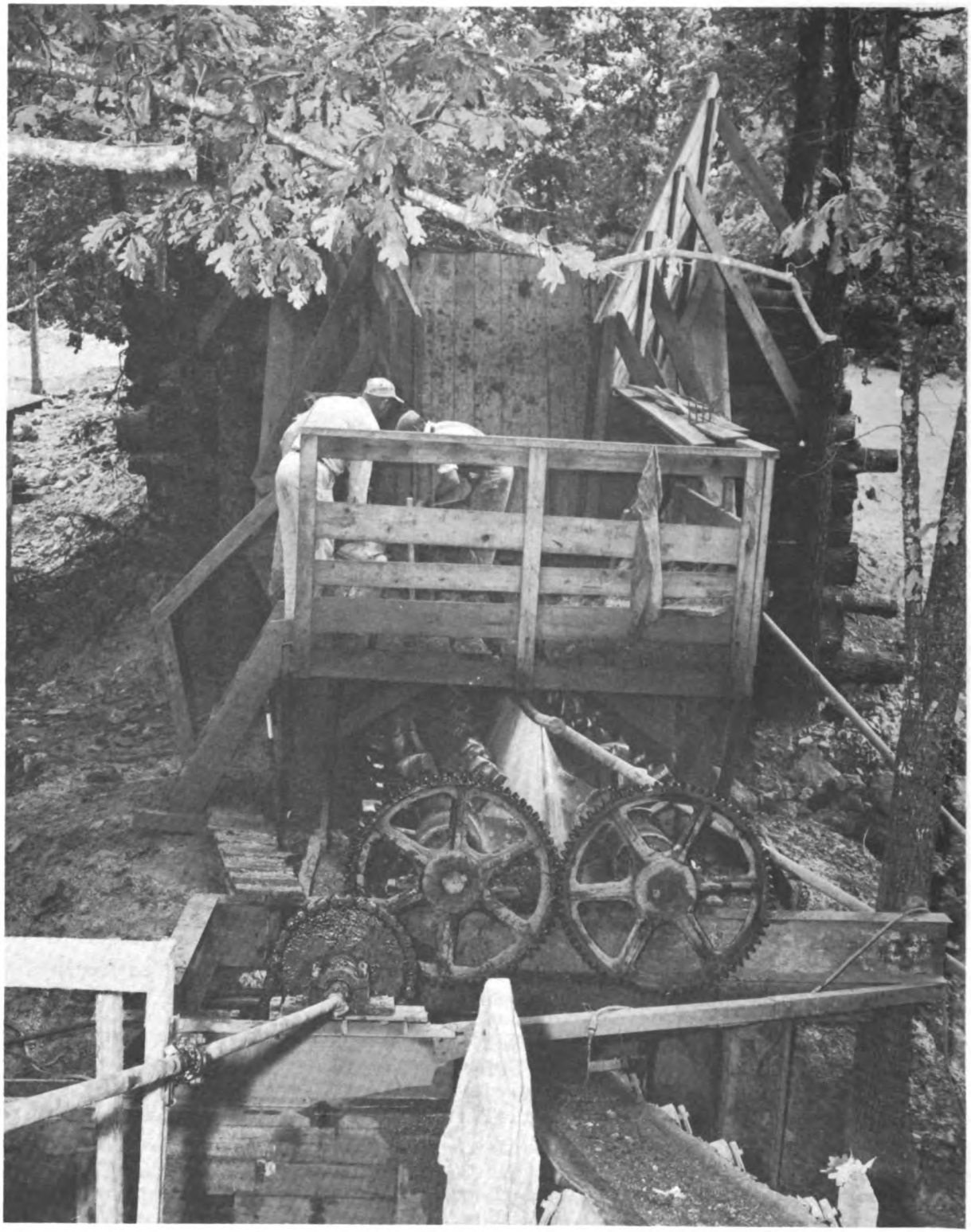

FIGURE 7. - Log Washer and Picking Belt, Four Mining Co., Howell County, Mo.

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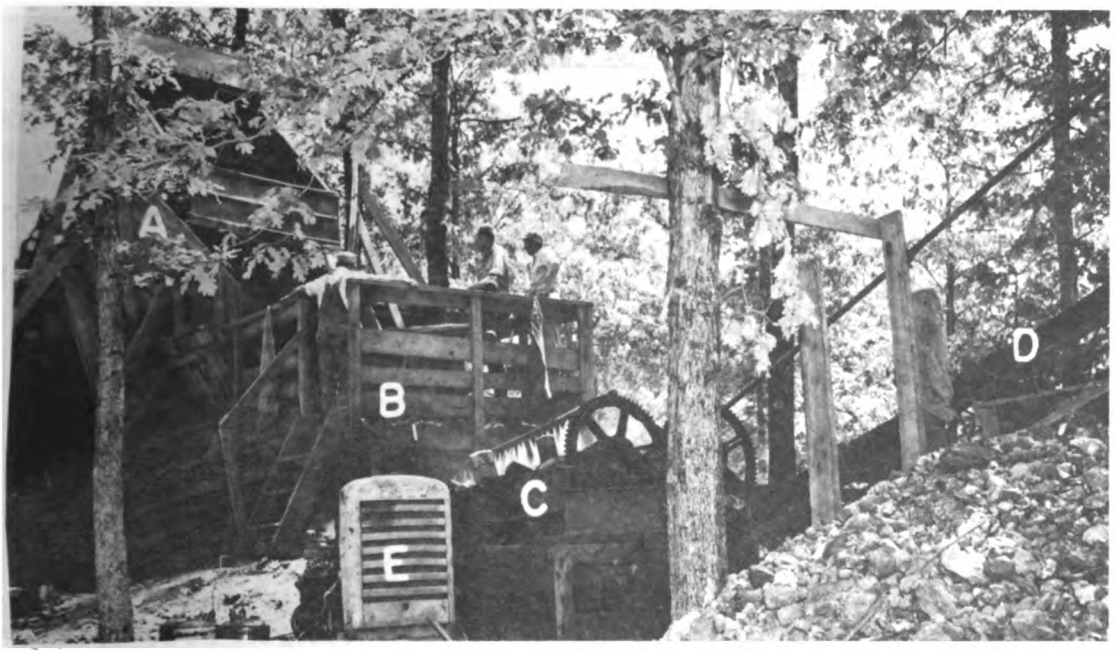

FIGURE 8. - Washer Plant, Four Mining Co., Howell County, Mo. (A) Truck Dumping Into Hopper (B) Grizzly (C) Log Washer (D) Picking Belt (E) Power Plant.

TRANSPORTATION

Haulage at each mine was by 5-cu.-yd.-capacity end-dump trucks; five were used at the Sawyer mine and two at the Fore mine. The distance by road from the Sawyer mine to the washer at Williamsville is 11 miles; at the Fore mine the haul from the pit to the washer was about 500 ft. Haulage from the Sawyer mine was done with privately owned trucks on a contract price per ton; the trucks at the Fore mine were company owned and operated.

Roads in and within a few hundred feet of the pits were built with local material and were not surfaced; they become slippery when wet and were the cause of shutdowns during rainy weather. All-weather, gravel-surfaced access roads, less than a mile long, extend from the pit roads to hard-surfaced highways.

Haulage costs averaged 6.25¢ per long-ton mile.

PRODUCTION RATES AND PERCENTAGE OF EXTRACTION

Sawyer Mine

During 1957, the Sawyer mine operated one 8-hr. shift per day for 192 days. Crude ore, estimated by the operator to contain 38 pct. iron, 0.05 pct. phosphorus, and 3.88 pct. insoluble material, was mined at an average daily rate of 205 wet long tons per day. Total output from the mine during 1957 was 39,270 wet long tons of crude ore, which produced 17,000 dry long tons of shipping-grade ore averaging 58 pct. iron, 0.05 pct. phosphorus, and 4 pct. insoluble material. The data indicate a recovery of 66 pct. of the iron in the crude ore.

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Fore Mine

During 1957 the Fore mine operated one 8-hr. shift per day for 200 days. Daily production averaged 310 wet long tons of crude ore estimated by the producer to contain 35 pct. iron, 0.04 pct. phosphorus, and 5 pct. insoluble material. Total output from the mine during the year was 62,448 wet long tons of crude ore, from which 20,816 dry long tons of shipping-grade ore was recovered averaging 50 pct. iron, 0.06 pct. phosphorus, and 8 pct. insoluble material.

All material estimated to contain enough iron to be profitably handled was mined and washed.

The data indicate a recovery of 47.58 pct. of the iron in the crude ore.

MINE DRAINAGE

The floor of each pit was normally advanced upgrade to prevent the accumulation of water. Rainwater drained through the lowest pit opening, or was allowed to seep through pit bottoms.

WAGES, OPERATIVES, AND EQUIPMENT

Prevailing wage rates in the brown-iron-ore mines of southern Missouri in 1957 ranged from $1.00 per hour for common labor to $1.50 per hour for heavy equipment operators. Much of the hauling and bulldozer work was done on a contract basis.

Job classifications, the number of operatives in each category, and the basic hourly wage of the two companies in 1957 are given in table 2.

Units of equipment employed by the two companies follows:

Wayne County Mining Co.:

Bulldozer (contract work)	1
Front-end loader (2-1/2-cu.-yd. skip)	1
Front-end loader (1-1/2-cu.-yd. skip)	1
Dump trucks (5-cu.-yd. capacity)	6
Hauling ore from pit to washer	5
Hauling concentrate from washer to railhead	1
Washer with picking belt	1
Exploration churn drill	1

Four Mining Co.:

Dipper shovel (1-cu.-yd. dipper)	1
Front-end loader (1-1/2-cu.-yd. skip)	1
Dump truck (5-cu.-yd. capacity)	6
Hauling ore from pit to washer	2
Hauling concentrate from washer to railhead	4
Washer with picking belt	1

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MARKETING ORES

Brown iron ores produced in southern Missouri are normally sold to blast-furnace operators in Illinois and Alabama. The price is based on units (22.4 lb.) of iron per dry long ton, and the ore is sold under schedules submitted to the producers by individual purchasers. Table 3 gives a typical price schedule as of June 1957, and table 4 gives typical furnace specifications for Missouri brown ores. Penalties may be assessed or the ore rejected if the sulfur, phosphorus, or other objectionable elements exceed allowable quantities.

TABLE 2. - Operatives

Job classification	Number of men	Basic hourly wage rate
Wayne County Mining Co.:		
Bulldozer operator	1	$1.50
Loader operator	1	1.50
Truckdrivers	5	1.00
Washer operators	3	1.00
Total	10	
Four Mining Co.:		
Loader operators	1	1.50
Truckdrivers	2	1.10
Washer operators	3	1.10
Total	6	

TABLE 3. - Typical price schedule for Missouri brown iron ores, June 1957 (4)

Combined Fe and Mn (dry), pct.	Price f.o.b. shipping point per unit per gross ton
40 to 45	$0.100
45 to 47	.105
47 to 50	.125
50 to 53	.135
53 and over	.140

TABLE 4. - Typical furnace specifications for Missouri brown iron ores (4)

	Pct.
Fe (dry) minimum	40.00
Silica maximum	15.00
Sulfur maximum	.15
Phosphorus maximum	.25
Size in inches	1/4-4

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TABLE 5. - Summary of mining and washing costs

Year: 1957
Mining method: Open-pit

	Cost per WLT crude ore mined and washed[1]			Cost at washer per DLT shipped[2]		
	Labor[3]	Supplies, parts and repairs	Total	Labor	Supplies, parts and repairs	Total
Sawyer mine, Wayne County Mining Co.:						
Stripping	$0.059	$0.175	$0.237	$0.136	$0.412	$0.548
Mining and loading	.059	.254	.313	.140	.590	.730
Hauling (mine to washer)	.196	.391	.587	.452	1.089	1.541
Washing	.117	.294	.411	.271	.682	.953
Total	.431	1.117	1.548	.999	2.773	3.772
Percent of total	27.84	72.16	-	26.48	73.52	-
Hauling, washer to railroad (1/4 mile) and loading on car	-	-	-	-	-	.320
Total cost per DLT loaded on railroad car	-	-	-	-	-	4.092
Fore mine, Four Mining Co.:						
Stripping	-	-	-	-	-	-
Mining and loading	$0.038	$0.136	$0.174	$0.115	$0.407	$0.522
Hauling (mine to washer)	.056	.128	.184	.169	.383	.552
Washing	.085	.264	.349	.254	.793	1.047
Total	.179	.528	.707	.538	1.583	2.121
Percent of total	25.32	74.68	-	25.37	74.63	-
Hauling, washer to railroad (23 miles) and loading on car	-	-	-	-	-	1.323
Total cost per DLT loaded on railroad car					-	$3.444

1/ Wet long tons (WLT) of crude ore mined and washed during 1957: Sawyer mine, 39,270: Fore mine, 62,448.
2/ Dry long tons (DLT) shipped during 1957: Sawyer mine 17,000: Fore mine, 20,816.
3/ Includes industrial insurance.

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TABLE 6. - Summary of costs in units of labor

Year: 1957
Mining method: Open-pit

	Wayne County Mining Co.		Four Mining Co.	
	Man-hours per WLT crude ore mined and washed	Man-hours per DLT shipped	Man-hours per WLT crude ore mined and washed	Man-hours per DLT shipped
Stripping	0.039	0.090	-	-
Mining	.039	.090	0.026	0.077
Hauling (mine to washer)	.196	.452	.051	.154
Washing	.117	.271	.077	.231
Total	.391	.903	.154	.462
Percentage of total labor cost:				
Stripping	9.97	9.97	-	-
Mining	9.97	9.97	16.88	16.67
Hauling	50.13	50.06	33.12	33.33
Washing	29.93	30.00	50.00	50.00
Wet long tons (WLT) crude ore mined and washed	39,270		62,448	
Dry long tons (DLT) shipped	17,000		20,816	
Tons crude ore per man-shift mined and washed	20.45		52.00	
Tons per man-shift, upgraded ore shipped	8.85		17.3	

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